GROSS AND NET YIELD TABLES for LODGEPOLE PINE

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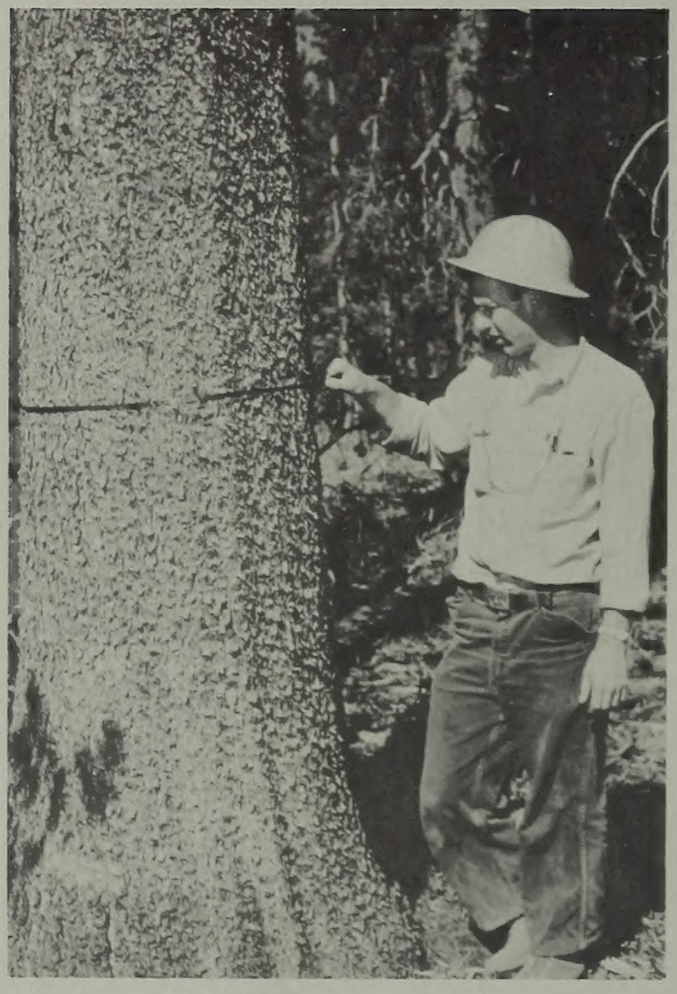

A 25-inch lodgepole pine
growing on the
Winema National Forest

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CONTENTS

INTRODUCTION

Gross and net yields of lodgepole pine (Pinus contorta) are presented in this paper for the pumice soil areas of central and south-central Oregon. Both types of yield are given in terms of cubic feet of peeled volume for all stems 1.0 inch d.b.h. and larger. The site index curves upon which the yield figures are based are also presented.

Gross yield represents all of the wood produced. It represents the net yields ordinarily presented in normal yield tables plus the volume of all trees that died.

Gross yield may also represent a potential value that intensive management can approach but never quite reach when the genetically unimproved species is grown on its natural site. As such, it represents a bench mark foresters can use to measure success of their own management practices.

METHODS

Methods used to obtain gross yield differed from the usual yield table procedures. Gross yield was obtained as a cumulative summary of gross increment.[1/]

Gross basal area and volume increments were estimated on each plot from growth measurements taken on a sample of felled trees and diameter measurements on all trees. Multiple regression methods were used to relate these plot values to the stand values--age, site index, and density.

Volume and basal area found on plots at the time of examination were accepted as net yield and net basal area. Plot values were related to the stand variables--age and site index--by regression methods.

Site index was developed from sectioned trees using methods described by Johnson and Worthington (1963). The original intent was

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[1/] Increment added by trees that died during the 10-year growth period is actually a part of gross increment but is not included in this case. However, increment thus neglected is so small that it is of little consequence.

to base the index on average height of the 30 tallest trees per acre (6 per 1/5-acre plot). However, to correct a bias caused by shifts in relative height of trees with the passage of time, it became necessary to use height of the single tallest tree per plot as the basis (Dahms, 1963). Subsequent tests showed an estimate of site index, obtained from the single tallest tree per plot, was almost as good as that obtained from the six tallest trees.

Plot Selection and Distribution

Sampling objectives were twofold: (1) to obtain a good geographical representation of lodgepole pine stands as they occur on pumice soils in central and south-central Oregon and (2) to sample, for each 10-year age span from 30 to 120 years, 10 stands representing the widest possible range in site quality. Plot locations were further limited to pure, even-aged stands with densities high enough to fully occupy the site but not so high that height growth of the tallest trees would be retarded. Tenth-acre plots were used in less than 50-year-old stands and 1/5-acre plots in older stands.

Altogether, 94 plots representing stands varying from 28 to 161 years of age were selected and measured.

Basic Data

The following basic data were taken on each plot:

1. D.b.h. outside bark of all trees.

2. Total height of the six tallest trees on each plot.

3. D.b.h. inside bark and total height of from 15 to 24 trees per plot at the time of measurement and 10 years earlier. These trees were felled.

4. Total age of all felled dominant and codominant trees.

The following additional data were obtained on some plots:

1. On the first 60 plots, at least three trees per plot were measured for volume table purposes.

2. The tallest six trees were sectioned for site index curve construction purposes on 13 plots.

Derived Values

The following values were derived for each plot from the basic measurements:

1. Basal area.

2. Cubic volume inside bark.

3. Gross basal-area increment during the past 10 years.

4. Gross cubic-volume increment during the past 10 years.

5. Average stand age.

6. Site index.

7. Crown competition factor.[2/]

[2/] Crown competition factor is a measure of stand density described by Krajicek, Brinkman, and Gingrich (1961). Necessary crown-width measurements on free-growing trees were taken by personnel of the Pacific Northwest, Intermountain, and Rocky Mountain Forest and Range Experiment Stations within their own territories. The formula

$$C = \frac{1}{A}\left[0.0192N + 0.0168\Sigma D + 0.0036\Sigma D^2\right]$$

where C = crown competition factor

A = plot area in acres

N = number of trees

D = diameter breast high outside bark

was calculated at the Rocky Mountain Station for the combined data.

REASONABLENESS OF RESULTS

The two tests used to determine reasonableness of results were:

1. A comparison of gross and net yields obtained in this study and

2. A comparison of gross yield in this study with net yield from the British Columbia yield table (1947).

For site index 50, lodgepole pine net yield represents 68 percent of gross yield at age 80 years and 63 percent at age 120 years. Similarly, net yield from the British Columbia yield table represents 78 and 70 percent of gross yield in the present study at age 80 and 120 years respectively.[3/]

The ratio of net to gross yield found in the present study bears a reasonable relationship to similar ratios for Douglas-fir (Pseudotsuga menziesii), and ponderosa pine (Pinus ponderosa). Net yield for site III Douglas-fir represents 79 and 73 percent of gross yield at ages 80 and 120 years, respectively (Staebler, 1955). Similarly, net yield of

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[3/] Site index 50 in the present study was estimated to be the equivalent of site index 57 in the British Columbia yield table site index system (average height of dominant and codominant trees at age 80 years). Average height of dominant and codominant trees was estimated from height of the single tallest tree per 1/5-acre plot with the equation:

$$H_a = -1.84 + 0.892H_t$$

where H_a = average height of dominant and codominant trees

H_t = height of tallest tree

Similarly, height of the single tallest tree per 1/5-acre plot can be estimated from the equation:

$$H_t = 2.06 + 1.12H_a$$

ponderosa pine represents 79 and 74 percent of gross yield at ages 80 and 120 years (Meyer, 1938).[4/]

The most obvious reason for the greater difference between net and gross yields in the present study is choice of plots in less than full or normal density.[5/] The result is that net yield drops in direct proportion to density. Gross increment from which gross yield is derived, however, is much less affected.

APPLICATION

Gross yield figures presented herein provide for at least the following estimates and uses:

1. An estimate of the total wood-producing capacity of lodgepole pine in terms of cubic feet.

2. An opportunity to compare the productive capacity of a given site for lodgepole pine and some other species, provided there is a gross yield table for the other species and both can be found growing on the same site.

3. An estimate of culmination age for gross mean annual increment.

Results obtained with this yield table are heavily dependent upon accurate site index estimates. Reduction of height growth by overdensity is probably the greatest obstacle to obtaining such estimates. Smithers (1956) has shown that height growth of lodgepole pine is substantially reduced by only moderate overdensity. The average density of stands in the present study appears to represent a safe upper density limit for

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[4/] Gross yield for ponderosa pine was estimated by adding together net yield and mortality as given by Meyer (1938). Meyer called his mortality estimate a minimum one because of his assumption that mortality was limited to the smallest trees in the stand.

[5/] Normal density is used here in the sense of full stocking in the usual normal yield table.

stands where site index is to be measured. This density, expressed in terms of crown competition factor, is:[6/]

$$C = 203.46 - 0.4354Y$$

where Y = age in years

Stands that have been reduced to presently acceptable density standards by heavy mortality should also be avoided.

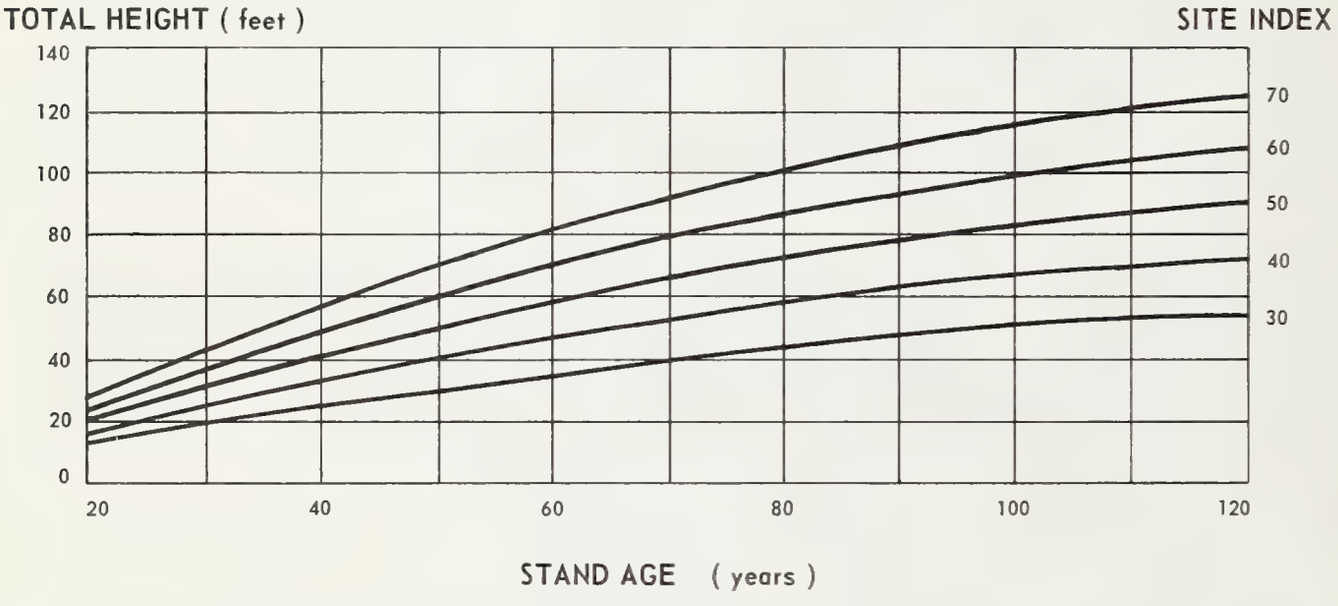

Figure 1.--Height of tallest tree per one-fifth acre, by stand age and site index.

[6/] See footnote 2, page 3, and footnote 1, table 3.

Table 1.--Factors for calculating site index[1/]

Age (the even multiples of 10 years)[2/]	Individual years for each decade									
	0	1	2	3	4	5	6	7	8	9
	Site index factor									
20	2.488	2.353	2.237	2.128	2.028	1.942	1.862	1.792	1.724	1.661
30	1.605	1.553	1.504	1.458	1.416	1.376	1.339	1.304	1.271	1.241
40	1.211	1.183	1.157	1.133	1.109	1.087	1.066	1.045	1.027	1.008
50	1.000	.974	.958	.943	.928	.913	.900	.887	.874	.862
60	.851	.840	.829	.819	.809	.799	.790	.781	.773	.765
70	.756	.748	.741	.734	.727	.720	.714	.707	.701	.695
80	.690	.684	.678	.673	.668	.664	.659	.654	.649	.645
90	.641	.637	.633	.629	.625	.622	.618	.615	.612	.609
100	.606	.602	.600	.597	.595	.592	.589	.587	.585	.582
110	.580	.578	.576	.574	.572	.570	.569	.567	.566	.564

[1/] Factors are reciprocals of denominators for the equation:

$$S = \frac{H_t}{-0.0968 + 0.02679Y - 0.00009309Y^2}$$

where S = site index

[2/] To use, determine breast-high age on one to three dominant trees, including the tallest one. Add 10 years to average breast-high age of trees for which age was counted. Apply to the above table with average calculated total age to get proper site index factor. To obtain site index, multiply this factor by height of the tallest tree on a 1/5-acre plot.

Table 2.--Net yield per acre for lodgepole pine[1/]

Age (years)	Site index				
	30	40	50	60	70
	Cubic feet				
30	487	843	1,198	1,553	1,909
40	813	1,287	1,761	2,234	2,708
50	1,120	1,712	2,304	2,896	3,488
60	1,402	2,112	2,823	3,534	4,245
70	1,655	2,484	3,314	4,143	4,972
80	1,875	2,823	3,770	4,718	5,665
90	2,056	3,122	4,188	5,255	6,321
100	2,194	3,379	4,563	5,748	6,932
110	2,284	3,587	4,890	6,193	7,496
120	2,321	3,743	5,164	6,585	8,007

[1/] Values are for the plots' average stocking, ranging from a crown competition factor of 190 at age 30 to 151 at age 120. Average crown competition factor is expressed by the equation:

$$C = 203.46 - 0.4354Y.$$

It is believed that crown competition factor rather than actual density is correlated with age. Volume per acre for this average density is expressed by the equation:

$$V = 557 - 0.000802Y^3 + 1.1845YS$$

where V = stand volume in cubic feet per acre.

All trees 1.0 inch d.b.h. and larger with stumps and tops included.

Table 3.--Net basal area per acre for lodgepole pine[1/]

Age (years)	Site index				
	30	40	50	60	70
	Square feet				
30	101	106	110	114	118
40	105	111	117	122	128
50	109	116	123	130	138
60	112	121	130	138	147
70	116	126	135	145	155
80	118	130	141	152	164
90	120	133	146	159	172
100	122	136	151	165	179
110	123	139	154	170	186
120	124	141	158	175	192

[1/] Values are for the plots' average stocking, ranging from a crown competition factor of 190 at age 30 to 151 at age 120. Average crown competition factor is expressed by the equation:

$$C = 203.46 - 0.4354Y.$$

It is believed that crown competition factor rather than actual density is correlated with age. Basal area per acre for the average density is expressed by the equation:

$$B = 88.9 + 0.01424YS - 0.000009545Y^3$$

where B = stand basal area in square feet per acre.

All trees 1.0 inch d.b.h. and larger with stumps and tops included.

Table 4.--Mean annual net increment per acre for lodgepole pine[1/]

Age (years)	Site index				
	30	40	50	60	70
	Cubic feet				
30	16.2	28.1	39.9	51.1	63.6
40	20.3	32.2	44.0	55.9	67.7
50	22.4	34.2	46.1	57.9	69.8
60	23.4	35.2	47.1	58.9	70.8
70	23.6	35.5	47.3	59.2	71.0
80	23.4	35.3	47.1	59.0	70.8
90	22.8	34.7	46.5	58.4	70.2
100	21.9	33.8	45.6	57.5	69.3
110	20.8	32.6	44.4	56.3	68.1
120	19.3	31.2	43.0	54.9	66.7

[1/] All trees 1.0 inch d.b.h. and larger with tops and stumps included.

Table 5.--Gross yield per acre for lodgepole pine[1/]

Age (years)	Site index				
	30	40	50	60	70
	Cubic feet				
25	319	615	911	1,207	1,503
30	588	986	1,383	1,781	2,178
40	1,110	1,705	2,299	2,894	3,488
50	1,610	2,393	3,176	3,959	4,743
60	2,087	3,050	4,014	4,978	5,941
70	2,541	3,677	4,813	5,949	7,085
80	2,973	4,273	5,573	6,873	8,173
90	3,382	4,838	6,294	7,749	9,205
100	3,768	5,372	6,975	8,578	10,182
110	4,132	5,875	7,618	9,360	11,103
120	4,472	6,346	8,221	10,094	11,969

[1/] Gross yield is net yield to age 25 plus cumulative gross increment obtained by integrating the equation

$$G_v = 1.42 - 0.0439C + 0.01109CS - 0.003366SY$$

where G_v = gross annual volume increment in cubic feet per acre

with respect to age from 25 years to the desired age. The resulting formula for gross per-acre cubic-foot yield is:

$$-570 + 29.61S + \left[-7.52 + 2.256S\right](Y - 25)$$

$$-\left[0.0098 + 0.004103S\right](Y^2 - 625).$$

The gross increment equation accounted for 74 percent of all between-plot variation. Stand density (C) represents the average found on all plots adjusted for age. This average is expressed by the equation

$$C = 203.46 - 0.4354Y.$$

All trees 1.0 inch d.b.h. and larger with tops and stumps included.

Table 6.--Mean annual gross increment per acre for lodgepole pine[1/]

Age (years)	Site index				
	30	40	50	60	70
	Cubic feet				
25	12.8	24.6	36.4	48.3	60.1
30	19.6	32.9	46.1	59.4	72.6
40	27.8	42.6	57.5	72.4	87.2
50	32.2	47.9	63.5	79.2	94.9
60	34.8	50.8	66.9	83.0	99.0
70	36.3	52.5	68.8	85.0	101.2
80	37.2	53.4	69.7	85.9	102.2
90	37.6	53.8	69.9	86.1	102.3
100	37.7	53.7	69.8	85.8	101.8
110	37.6	53.4	69.3	85.1	100.9
120	37.3	52.9	68.5	84.1	99.7

[1/] All trees 1.0 inch d.b.h. and larger with tops and stumps included.

Table 7.--Gross annual per-acre basal-area increment for site index 50 lodgepole pine[1/] [2/]

Age (years)	Basal area	Age (years)	Basal area
	-- Square feet --		-- Square feet --
25	5.0	75	1.6
35	3.6	85	1.4
45	2.7	95	1.4
55	2.2	105	1.3
65	1.8	115	1.3

[1/] Values derived from the equation:

$$G_b = 2.83 - \frac{448.06}{Y} + \frac{21,597.7}{Y^2} - \frac{300,693}{Y^3} + \frac{1.32051B}{Y} - 0.01725S$$

where G_b = gross annual basal-area increment in square feet per acre.

This equation accounted for 89 percent of all between-plot variation.

[2/] Although the site index term was statistically significant, differences in values for the various site index classes were in such small amounts that there seemed little point in presenting more than the average site quality class values.

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